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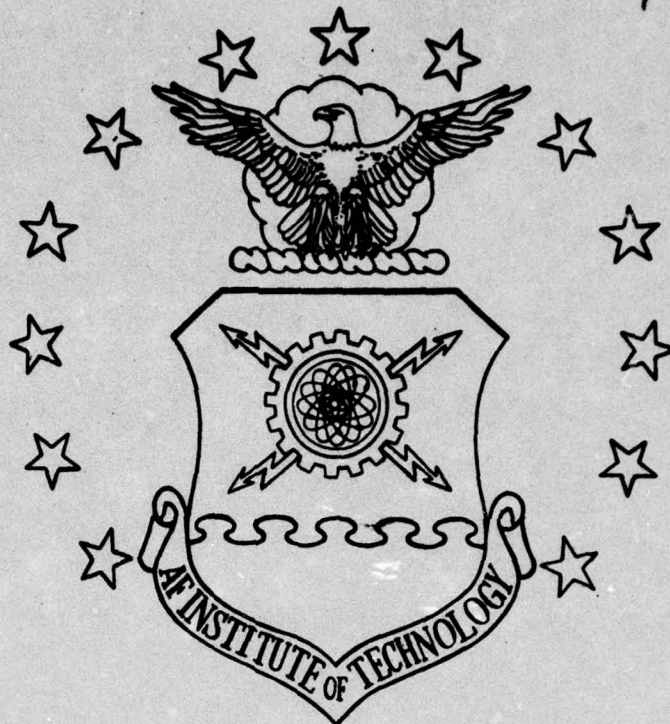
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Larry L. Smith, Lt Col, USAF

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previously constructed index number series developed and maintained by agencies external to the pricing office. The externally constructed index numbers may sometimes be substituted for index numbers tailored to a specific procurement, saving the analyst time in exchange for loss of accuracy. The task of forecasting index numbers is a time series analysis problem. Some statistical techniques such as regression analysis and exponential smoothing may be appropriate for this task. For short range forecasts, one may use graphical techniques with reasonable confidence. It is observed that in recent years index number series no longer follow a linear pattern with respect to time. Price index numbers may be used to analyze prices, adjust final prices paid to compensate for escalation of costs and deflate data to facilitate cost analysis. Examples of these uses are included in a final section of this paper.

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THE USE OF INDEX NUMBERS IN
DEFENSE CONTRACT PRICING

A School of Systems and Logistics AU-AFIT-SL Technical Report
Air University
Air Force Institute of Technology
Wright-Patterson AFB, Ohio

By
Larry L. Smith
Lieutenant Colonel, USAF

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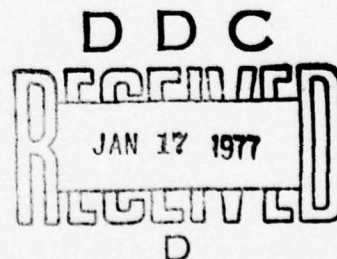


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PART I

PURPOSE AND OVERVIEW

The contracting community has need to employ many different tools and techniques in estimating the prices of future procurements. The high probability that costs and prices of goods and services will change over time requires development of approaches to estimate for that change. One set of approaches uses index numbers to forecast the change in price of goods and services.

The purpose of this paper is to show how index numbers can be used as a technique of contract pricing. It is intended for the use of students who want to know more about the procurement process as well as practitioners of the contract pricing discipline.

One of the variables with which the price analyst must contend is the changing value of the dollar as time progresses. Index numbers, in particular price index numbers, provide the analyst with a tool to treat the effect on price of the changing value of the dollar over time. The use of index numbers in pricing can be categorized as a comparison approach to price and cost analysis as differentiated from the detailed analysis approach. This is because price index numbers usually indicate historical

price changes with respect to time. These numbers can then be used to analyze, compare, and predict prices for a specific product or service in a different time frame.

There are a number of reasons one uses index numbers instead of the prices themselves to provide for the comparison. One reason is to reduce the comparison to percentage increase or decrease terms thus rendering price changes for high priced items comparable to price changes for low priced items. Another is to provide for comparing price changes over time of aggregates of different items such as aggregative price changes for apples and oranges or plywood and nails. A third reason is to provide a vehicle for aggregating samples of price changes for different items and using the aggregated sample to represent price changes for an entire population of items.

The price analyst uses index numbers for three general purposes; to deflate or inflate prices for comparison analysis, to project price or cost escalation in contractual documents and to inflate or deflate costs to facilitate trend analysis. Index numbers are used in price analysis to compare the proposed cost of an item with the cost of a same or similar item procured in past years. Here, the index numbers are used to discount inflation that has occurred over time so the comparison can be made in constant year dollars. Escalation clauses usually call for

some kind of after-the-fact pricing action adjusting the price paid to reflect actual price levels at the time of the contract performance. These clauses use index numbers to measure the change in price levels over time. Index numbers are also used to facilitate trend or time-series analysis of individual cost elements by eliminating or reducing the effects of inflation. The analysis can then be performed in constant dollars.

These three uses of index numbers will be discussed in this paper along with some examples. In addition, this paper will deal with index number construction, previously constructed index numbers, and methods for forecasting changes in index numbers as time changes.

PART II

INDEX NUMBERS DEFINED

Index numbers are ratios, usually expressed as percentages, indicating changes in values, quantities or prices. Typically, the changes are measured over time, each item being compared with the corresponding figure from some selected base period. Simple index numbers deal with homogeneous denominations representing commodities such as plywood, steel, or grain. More commonly though, index numbers are aggregates of a number of different commodities, products or services. Each item in the aggregation is weighted to represent a commodity, product or service in proportion to its amount in a particular end item, industry or geographical region.

Index numbers are commonly classified into three different types; price, quantity and value. A series of price index numbers represent changes in prices of items, commodities or industries over time. An example of a price index number series is the Wholesale Price Index (published monthly by the Bureau of Labor Statistics) which represents the change, over time, in the average wholesale prices of commodities and products sold in the United States. A quantity index measures the change in the amount of a

commodity or product output over periods of time. The Federal Reserve Board compiles a quantity index called the Index of Industrial Production which measures physical volume of factory production in the United States from one year to the next. A value index combines changes in both price and quantity over time. Value indexes can be considered to be the product of a price index and quantity index. A commonly used value index is the Index of Retail Sales published in the Federal Reserve Bulletin which reflects the changes in both the prices and the quantities of items sold by retail sales outlets across the United States.

When dealing with index numbers, it is important to identify the type of index number one is working with and use that type of index number consistently throughout the analysis. Naturally, when one is in the business of analyzing prices, he will be mostly concerned with price index numbers.

PART III

CONSTRUCTING PRICE INDEX NUMBERS

Price index numbers indicate price changes with respect to time for some specific commodity, product or service. As historical indicators, index numbers become more accurate if they are constructed using actual prices paid for a particular commodity, product or service rather than using the more general aggregative index numbers published by agencies such as the Bureau of Labor Statistics. Accordingly this section will treat five methods of price index number construction including examples. They are; simple price indexes, simple aggregative price indexes, weighted aggregative price indexes of the Laspeyres and Paasche types, and weighted average of relatives indexes. A short discussion of selecting the base period is included before presenting the individual methods of construction.

The Base Period

Price index numbers are price relatives, usually expressed as percentages. As price relatives, they relate prices paid in one time period to prices paid in some base time period. To provide comparability, a series of index

numbers representing some commodity, product or service is always constructed using the same base period, thus reflecting a percentage increase or decrease in prices relative to that base period.

The selection of a base period is usually an arbitrary process. On a short series of data, say five to ten years, the analyst often chooses the first (earliest) year as the base year. Under ideal conditions, it is best to choose as a base year a year in which prices are not changing erratically. This is difficult when hundreds of items are included in an aggregative index number and leads one back to an arbitrary choice of a base year.

The U.S. Department of Labor, Bureau of Labor Statistics (BLS), a widely recognized constructor and publisher of general index numbers, currently uses a base year of 1967 for their index numbers. The BLS changes their base year periodically, usually on the decade. For example in 1980, the BLS may update their index number series to a new year of 1977.

A shift in a series of index numbers to a new base year is a straightforward calculation if it is known that the original sample of goods and services remains representative of the price changes to be indicated. For example, consider the problem of adjusting a 1976 index number with a base year of 1967 to a base year of

1972. In addition to the value of the 1976 number (say 151.9) one needs the value of the corresponding number in the same series in 1972 (say 118.0). The conversion is accomplished by dividing the index number to be changed by its corresponding value from the new base year and expressing the result as percentage. In this example the 1976 index number with a new base year of 1972 would be $(100 \times 151.9 \div 118.0)$ or 128.7.

The same information is relayed by the revised index number series as the initial series. Only the base year has been changed. Because the BLS uses a base year of 1967 for construction of so many indexes, many analysts arbitrarily pick 1967 as a base year when constructing indexes.

Simple Price Indexes

A simple price index series is usually a time series of price relatives converted to percentages. A price relative in this case is the average price of an item for a given time period (e.g., a given year) divided by the average price of an item for the base time period.

In constructing price index numbers, it is important to express a price in dollars per measure of quantity (e.g., \$/#, \$/person or, \$/ft.²). These measures of quantity are used in the construction of the weighting

factors for weighted aggregative index numbers. One should not express the price in terms of dollars per period such as is found in accounting data. Accounting data need to be edited to dollars per measure of quantity before their use in price index number construction.

There are four steps to be followed in constructing a simple price index number. They are: (1) Collect or develop average time series price data for the product, commodity, or service to be analyzed. For example, assume the average yearly prices of 1/4 inch thick, 4 feet by 8 feet, grade AC, interior, sanded plywood per 1000 square feet are:

Year	1967	1969	1971	1973	1975
Price	\$84.12	\$95.06	\$107.32	\$121.35	\$152.72

(2) Select a base year; say 1967, (3) Calculate a time series price relative for each year by dividing each price by the base year price, (4) Convert the series to an index number or percentage.

Year	1967	1969	1971	1973	1975
Price Relative	1.000	1.130	1.276	1.443	1.816
Index Number	100.0	113.0	127.6	144.3	181.6

These index numbers indicate the percentage change in price with respect to the base year only. The index for 1971 of 127.6 indicates that the average price of plywood

went up 27.6 percent with respect to 1967. It does not indicate that the average increase was 14.6 percent (127.6-113.0) with respect to 1969. To calculate the percentage increase in price for 1971 with respect to 1969 one would divide the 1969 index into the 1971 index, multiply the dividend by 100 and subtract 100.0.

$$100 [(127.6 \div 113.0)] - 100.0 \text{ or } 12.9 \text{ percent}$$

Mathematical notation is useful in expressing different methods of index number construction. For constructing simple price indexes the notation is

$$I_j = 100 \left[\frac{P_j}{P_0} \right]_0^n \text{ where } j$$

is a subscript denoting different periods ranging from 0 to n. In this instance P_0 is the price during the base year 0. P_j are the price values for the different years, e.g., $P_0 = \$84.12$ and $P_2 = \$95.06$. I_j are the indexes for the different years, e.g., $I_0 = 100.0$, and $I_2 = 113.0$.

Seldom will a single simple index number suffice for pricing purposes. Most items that are purchased are made up of many different materials and types of labor, the prices of which vary at different rates as time proceeds. Therefore, the analyst must construct composite index numbers that reflect aggregative changes in the prices of the components, assemblies, and types of labor that make up an item. This need has been satisfied by developing a

number of different methods for constructing aggregative indexes. The easiest of these methods is the simple average of relatives approach.

Average of Relatives Price Indexes

Simple average of relatives price indexes are constructed to indicate time series changes in prices of more than one item or commodity. Consider the construction of wooden boxes from plywood and nails. One can construct simple price indexes for nails in the same fashion that the indexes for plywood were constructed in a previous example.

Year	1967	1969	1971	1973	1975
Price per keg	\$15.20	\$15.65	\$16.00	\$15.92	\$18.10
Price relative	1.000	1.030	1.053	1.047	1.191
Index number	100.0	103.0	105.3	104.7	119.1

To construct a simple average of relatives price index reflecting an aggregative price change for plywood and nails, one sums the indexes for each commodity during a year and divides by the number of commodities. In this instance, with only two indexes, the calculations are easy. For example in 1969 the index is $(113.0 + 103.0) \div 2$ or 108.0.

Year	1967	1969	1971	1973	1975
Simple Aggrega- tive Price Index for Plywood & Nails	100.0	108.0	116.5	124.5	150.4

Continuing the practice of writing equations for index number construction, the general relationship for the simple average of relative price index is:

$$I_j = \sum_{i=1}^m \frac{I_{ij}}{m} = 100 \frac{\sum_{i=1}^m \frac{P_{ij}}{P_{i0}}}{m}$$

where $i = 1$ to m and relates to the different commodities, products or services that make up the index I .

and $j = 0$ to n and relates to the different periods from the first period 0 to period n .

For the first year as the base year.
 I_0 = aggregative index number for the base year.

An advantage of the simple average of relatives price index is that it permits the user to mix products with different dimensions. In this illustration one product with dimensions of 1000 ft² is mixed with another product with dimensions of kegs. This is done by reducing each product to a dimensionless ratio before combining.

A disadvantage of the simple aggregative pricing index method is that it implicitly assigns weights to each

of the products or commodities. Thus in the illustration, 1000 ft² of plywood has the same weight as one keg of nails. This weighting would be acceptable only if in constructing boxes, one keg of nails was needed for each 1000 ft² of plywood used. Seldom would that circumstance occur. Thus there is a need to weight each price relative in constructing an aggregative index number.

Choosing Weighting Factors

The quantities of each item or product in an aggregative index number are the logical candidates for explicit weighting factors. There is much discussion in the literature concerning which quantities to use, base year, current year or some mixture of each.

Base year quantities are the quantities of each item in the index purchased in the base year. In base year quantity construction, these quantities would be used to weight price relatives for all years of the time series, thus eliminating the effects of quantity changes from one year to another on the price index number. This approach does not recognize that in the real world the mix of items being purchased often changes from one year to another. Base year weighting is used in constructing price relatives of the Laspeyres type. Another approach, current year weighting, is used in constructing

aggregative price indexes of the Paasche type.

Weighted Aggregative Price Indexes of the Laspeyres and the Paasche Types

A common approach for index number construction is the fixed base year weighting approach developed by Etienne Laspeyres in 1964 (14:24). In addition to collecting time series price data for the different items to be aggregated, the approach requires collection of quantity data for the base year selected. The formulation of the Laspeyres methods is:

$$I_j = 100 \left[\frac{\sum_{i=1}^m P_{ij} Q_{i0}}{\sum_{i=1}^m P_{i0} Q_{i0}} \right]$$

where i stands for the different items numbered from 1 to m and j stands for the different periods. $j=0$ is the base period or year, thus P_{i0} stands for the base year price of the i th commodity and Q_{i0} stands for the base year quantity of the i th commodity.

Extending the plywood and nails example, one needs to collect quantity data as well as price data. Summarizing the data again:

Year	1967	1969	1971	1973	1975
Plywood $\frac{\text{Price}}{\text{M}}$	\$84.12	\$95.06	\$107.32	\$121.35	\$152.72
Plywood Qty. M	1000	1025	1025	1010	1015
Nails $\frac{\text{Price}}{\text{keg}}$	\$15.20	\$15.65	\$16.00	\$15.92	\$18.10
Nails Qty. Kegs	102	104	105	103	99

Note that the quantities are expressed in the same dimensions as the prices, e.g., plywood in 1000 ft² or M and nails in kegs. For the Laspeyres method of construction, only the base year (1967) quantities will be used for weighting purposes. For example:

$$I_{1975} = 100 \left[\frac{\sum_{i=1}^2 P_{i,1975} Q_{i,1967}}{\sum_{i=1}^2 P_{i,1967} Q_{i,1967}} \right]$$

$$= 100 \left[\frac{[(\$152.72)(1000) + (\$18.10)(100)]}{[(\$84.12)(1000) + (\$15.20)(100)]} \right] = 180.4$$

All calculations using the Laspeyres method of index number construction use base year quantities for weighting numbers. In a similar fashion, the rest of the index numbers calculated by the Laspeyres method are:

Year	1967	1969	1971	1973	1975
Index	100.0	112.8	127.2	143.6	180.4

In 1874, H. Paasche presented another approach for constructing index numbers which uses current period quantities as weights (14:25). The formulation of the

Paasche method is:

$$I_j = 100 \left[\frac{\sum_{i=1}^m P_{ij} Q_{ij}}{\sum_{i=1}^m P_{io} Q_{ij}} \right]$$

with the same meaning ascribed to the subscripts as previously defined. This index, like the Laspeyres index, is a ratio of weighted aggregates. But it relates the sum of current prices times current quantities to a hypothetical sum of base year prices times current quantities. Using the sample data for an illustration again:

$$I_{1975} = 100 \left[\frac{\sum_{i=1}^m P_{i,1975} Q_{i,1975}}{\sum_{i=1}^m P_{i,1967} Q_{i,1975}} \right]$$

$$= 100 \left[\frac{[(\$152.72)(1015) + (\$18.10)(99)]}{[(\$84.12)(1015) + (\$15.20)(99)]} \right] = 180.5$$

In a similar fashion, the rest of the index numbers calculated by Paasche method are:

Year	1967	1969	1971	1973	1975
Index	100	112.8	127.2	143.5	180.5

In the illustration, there was insufficient variation in the quantities purchased between the years to produce a significant change in the index numbers calculated.

Nevertheless, when there are many items in the calculations, and the variation in the quantities being purchased is significant, the different approaches will produce different results.

The Paasche and Laspeyres weighted aggregative indexes are superior to the simple indices previously discussed. By the weighting approach, they are freed from problems of distortion associated with the size of the units for which the prices are quoted. The Laspeyres index is essentially the same one used by the Bureau of Labor Statistics in constructing their extensive series of price indexes. As can be seen from the differences in formulation, the data gathering task is simpler for the Laspeyres construction since only base year quantity data are needed. There is considerable argument in the literature as to which, if either, of these two approaches is better. More complicated approaches have been devised such as the "Fisher" ideal index to try to eliminate any bias introduced by selecting only base year or current year quantities for weighting (14:28). There does not seem to be any conclusion as to a best method for index number construction.

Weighted Average of Price Relatives Indexes

Another method of index number construction using a weighted average of price relatives is introduced here

because it offers a practical means of combining previously constructed index numbers and specially constructed index numbers. This method is also well suited to using contractor accounting record data to construct the indexes. The formulation follows:

$$I_j = \sum_{i=1}^m I_{ij} \cdot W_{ij} \quad = \text{weighted average of relatives index number for given time period } j$$

where

$$I_{ij} = 100 \left[\frac{P_{ij}}{P_{io}} \right] \quad = \text{price relative of the } i\text{th commodity or service expressed in percentages; or a previously calculated index number from some source for the } i\text{th commodity and } j\text{th time period}$$

i = subscript denoting the i th commodity or service and ranging from 1 to m

j = subscript denoting the time period and ranging from the base period 0 to n

$$W_{ij} = \frac{P_{ij} Q_{ij}}{\sum_{i=1}^m P_{ij} Q_{ij}} \quad = \text{the relative weight of the } i\text{th commodity or service expressed as a relative of the total of all the commodities or services during the given time period.}$$

P_{io} = price (expressed in dollars per some unit of measure) of i th commodity or service in base time period 0

P_{ij} = price of i th commodity or service in j th given time period

Q_{ij} = quantity (unit of measure) of i th commodity or service in j th given time period

The approach is illustrated in Tables 1 through 5.

The illustration shows the computation of an employee

benefits index number for the years 1967, 1969, and 1975 using a weighted average of price relatives, weighted by current expenditures.

One can observe that instead of constructing a price relative for a particular item or service, one could substitute a previously constructed index number for I_{ij} in the formulation. Sources of previously constructed index numbers are discussed in the next section.

The Weighted Average of Price Relatives approach is suggested for use in the PIECOST system of estimating overhead costs of defense contractor(12:5-2). The ease of mixing previously constructed index numbers and specially constructed index numbers plus the advantage of using contractor cost data for weighting factors make it a practical method for the analyst to master.

TABLE 1
CONTRACTOR ACCOUNTING DATA

Year	1967	1969	1975
Nr. Indirect Employees	2000	2100	2150
Overhead Accounts			
1-Paid Absences	\$1,262,000	\$1,398,600	\$1,388,900
2-Employee Insurance	552,000	598,500	604,150
3-Savings-Retirement	810,000	894,600	991,150
4-Education	18,000	21,000	21,500
Total Employee Benefits	\$2,642,000	\$2,912,100	\$3,005,700

First, calculate prices from cost and volume data:

$$P_{ij} = \frac{\text{Amount paid in the year for service}}{\text{Quantity of service bought during the year}}$$

e.g., Price of Paid absences in 1967 = $\frac{\$1,262,000}{2000 \text{ person}} = \$631/\text{person}$

TABLE 2
PRICES

Year	1967	1969	1975
Overhead Accounts			
1	\$631	\$666	\$646
2	276	285	281
3	405	426	461
4	9	10	10

Second, calculate price relative (expressed as an index number) of average benefits per employee:

e.g., Price relative of paid absences in 1969 as compared to the base year 1967 is

$$100 \times \frac{P_{ij}}{P_{io}} = \frac{\$666}{\$631} = 105.5$$

TABLE 3

INDEX NUMBERS

(Base 1967) 100 x Price Relative

Year	1967	1969	1975
Overhead Accounts			
1	100.0	105.5	102.3
2	100.0	103.3	101.8
3	100.0	105.2	113.8
4	100.0	111.1	111.1

Third, calculate the relative weights of the benefits in each category for each year:

$$w_{ij} = \frac{P_{ij} Q_{ij}}{\sum_{i=1}^m P_{ij} Q_{ij}}$$

e.g., Calculate the relative weights of paid absences to total employee benefits for the year 1967:

$$\frac{\$1,262,000}{\$2,642,000} = .478$$

TABLE 4
RELATIVE WEIGHT OF BENEFITS

Year	1967	1969	1975
Overhead Accounts			
1	0.478	0.480	0.462
2	0.209	0.206	0.201
3	0.306	0.307	0.330
4	0.007	0.007	0.007
	<u>1.000</u>	<u>1.000</u>	<u>1.000</u>

Fourth, calculate index numbers for each year by summing the products of each account index number and its relative weight:

$$I_j = \sum_{i=1}^m I_{ij} \cdot W_{ij}$$

$$\text{e.g., } I_{1968} = 100 \left[\frac{(105.5 \times 0.480) + (103.3 \times 0.206) + (105.2 \times 0.307) + (111.1 \times 0.007)}{1.000} \right] = 105.0$$

TABLE 5
EMPLOYEE BENEFITS INDEX NUMBERS

Year	1967	1969	1975
Index Nr.	100.0	105.0	106.1

It is a matter of judgment on the part of the index number constructor whether to use current year data or base year data to construct the weighting factors. In the above example, current year quantities are indicated. The weighting factors are constructed from accounting data of the type usually available from contractor records.

PART IV

PREVIOUSLY CONSTRUCTED PRICE INDEX NUMBERS

Many times the analyst will not have sufficient data or time to construct index numbers needed for a particular analysis. There are many sources of previously constructed price index numbers that, although general in scope, may be used to approximate price changes of a particular product or service. Probably the best known and most frequently used sources of price index numbers are the "Wholesale Prices and Price Indexes" published monthly by the U.S. Department of Labor, Bureau of Labor Statistics (BLS). These economic indicators can also be found in the BLS publication "Monthly Labor Review" as well as a number of other publications. The wholesale price indexes are a series of indexes for prices of specific commodities and products. Each series is successively aggregated into homogeneous categories of items and commodities and finally into a general aggregation of wholesale prices for all production of the United States. Accordingly, one can choose among indexes for many different commodities or services and many different levels of aggregation to locate an index that fits a specific product. Another

widely used source of price index numbers is the "Survey of Current Business," National Income Issue, which is published each July by the U.S. Department of Commerce, Bureau of Economic Analysis. A series of Gross National Product Implicit Price Deflators are included in this publication. A source of data useful for constructing labor price index numbers is the BLS periodical "Employment and Earnings" which sets forth average wage rates segregated by skill and geographical categories. These rates are useful in tailoring an index to fit a specific product or company. Another source of wage data useful to the price analyst as an economic indicator is the annual "National Survey of Professional Administrative, Technical and Clerical Pay," a BLS publication. This Survey is useful as a source of data concerning indirect labor pay rate changes. The "Economic Report of the President," an annual publication of the Executive Branch, sets forth extensive summaries of economic indicators and is useful for evaluating long range trends of data. These sources are only a sample of many index number and economic data series available to the analyst.

A general index series must be used carefully since it usually will not exactly fit the cost pattern of the product or service being analyzed. Sources of error include the fact that the data are not from a specific

contractor, they usually are national or regional averages. Another error source is that the sample of items that make up an index probably will not fit a specific product or contractor effort. Nevertheless, preconstructed index numbers offer a practical alternative to the costly and time consuming task of building index number series from basic cost data.

PART V

FORECASTING INDEX NUMBERS

To this point, the discussions have been centered upon index numbers as a measure of history. The specially constructed price index numbers or the previously constructed price index numbers indicate changes of prices in times past. The business of defense contract pricing is concerned with predicting or forecasting prices in the future. Accordingly the analyst needs to be able to forecast index numbers as well as construct or extract them from the appropriate literature.

The forecasting problem can be divided into two categories; short range (up to two years) and long range (two to ten years). Generally speaking, for long range forecasts, one should use a trend analysis technique to build a model of the historical economic data change over time. A good source of the statistical techniques needed for trend analysis is the text by Leabo. It has been a time honored practice in Government procurement to best fit a straight line trend model through the historical data. This model is then used to forecast an index number in some future year. Recent changes in the rate of change of the economy indicate that the straight line is no

longer a good general trend indicator. Since 1965 the straight line trend forecast (based on indications from the 1960's) has consistently underestimated the future trend. Accordingly, a curved trend model of some form is more likely to predict accurately than the straight line.

For short range forecasting (less than two years) simple time series models such as the straight line are reasonably accurate. It makes good sense in short range forecasting to put more weight on the most recent years of data. One can do this subjectively by simply ignoring the early years of data, graphically fitting a straight line through the most recent data, and extending that straight line into future years for the forecast. A more objective approach to short term forecasting is through exponential smoothing, a mathematical method of giving extra weight to more recent data. An excellent discussion of exponential smoothing is included in a text by Brown listed in the Bibliography.

PART VI

USING PRICE INDEX NUMBERS IN DEFENSE CONTRACT PRICING

After obtaining or constructing a price index number time-series, the task remains to use these numbers to assist in cost or price analysis. Three general categories of uses will be discussed; to inflate or deflate prices for comparison analysis, to project cost or price escalation in contractual agreements, and to inflate or deflate costs to facilitate trend analysis.

Price Comparison Analysis

One of the uses of price index numbers is to measure price inflation. One can define price inflation as the time related increase in price of an item or service of constant quality and quantity. Price index numbers can be used to compare the prices of the same or similar items purchased in different time periods by inflating the old purchase price to a current time period or deflating a current price to some old purchase time period.

Consider the problem of analyzing a contractor proposal of \$85,500 for a turret lathe to be delivered in 1976. A procurement history file reveals that the same machine tool was purchased in 1972 at a price of \$48,500.

The task is to determine if the proposed price is fair and reasonable.

The approach is to; select or construct an appropriate index series, forecast the series to the anticipated date of production, inflate the old price to current dollars and compare. The Machinery and Equipment Subindex of the Wholesale Price Industrial Commodities Index (BLS) is selected as a reasonable indicator of price movement for the item. The data of Table 6 are extracted from the 1976 issue of the "Economic Report of the President" (13:226).

TABLE 6

MACHINERY & EQUIPMENT

Year	Index	Year	Index
1967 (base)	100.0	1973	121.7
1971	115.5	1974	139.4
1972	117.9	1975	161.4

The data needs to be forecasted to cover the anticipated period of production, 1976. This can be done by first graphing the data on rectangular coordinates, hand fitting a curve to the data, and projecting the curve into the future. See Figure 1.

For short range forecasts (2 years or less) the most recent data usually gives the best indication; therefore,

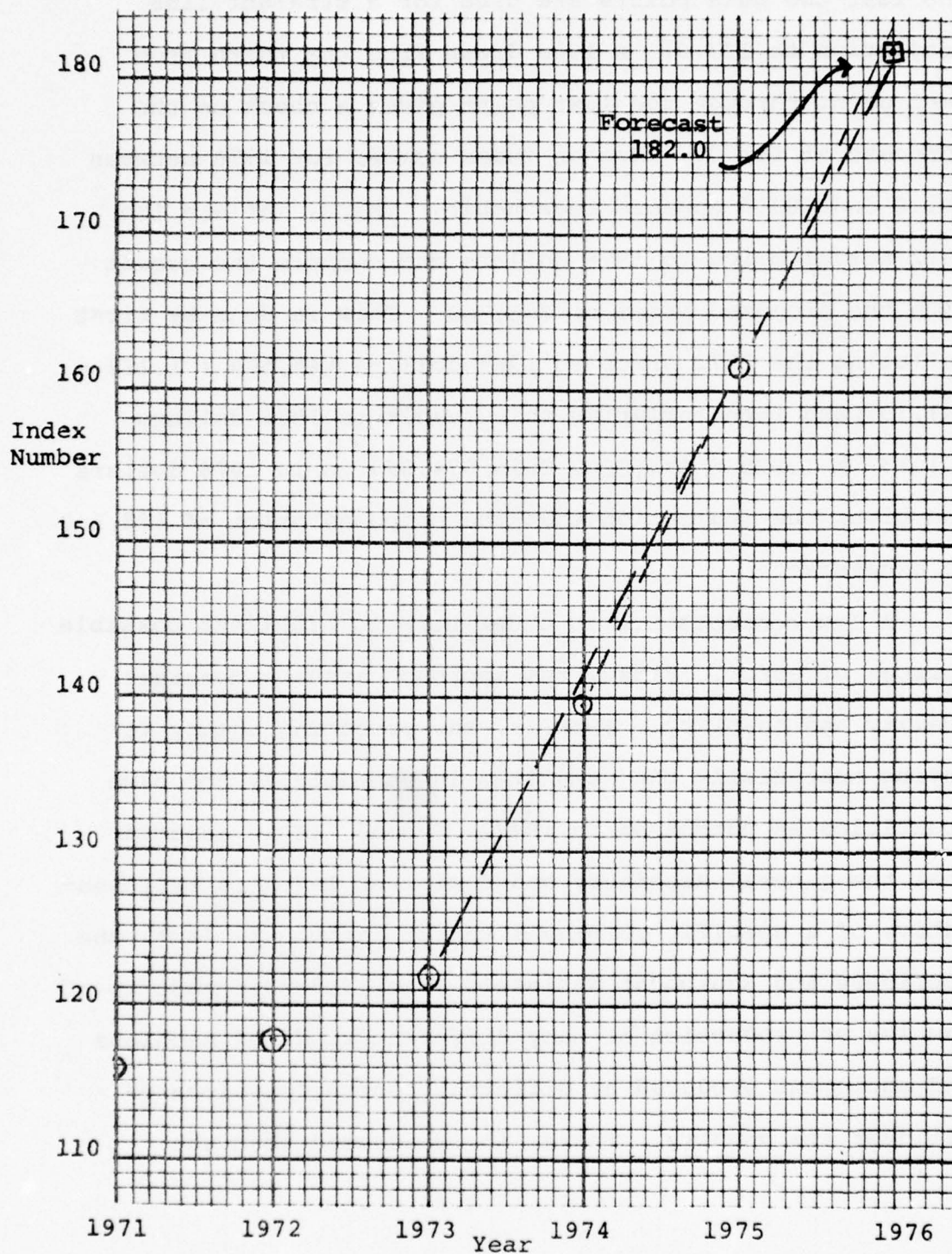


FIGURE 1
FORECASTING AN INDEX NUMBER

the last two data points are used for a straight line projection to 183.0. A line drawn from the third from last point through the last point gives a check on the forecast at 181.0. Thus an index number for 1976 between 181.0 and 183.0 appears reasonable. Third, inflate the 1972 actual price to 1976 dollars and compare the result with the proposed price of \$85,500. This is done by first deflating the 1972 price to 1967 dollars ($\$48,500 \div 1.179 = \$41,137$) and then inflating this result to 1976 dollars ($\$41,137 \times 1.820 = \$74,869$). This \$74,869 is in 1976 dollars and gives one indication that the proposed price of \$85,500 is excessive.

A few comments are in order here to highlight possible sources of error. First, the approach assumes constant quality and quantity. That is, the procuring agency is buying essentially the same item in essentially the same quantities as purchased in 1972. Second, it is assumed that the general Machinery and Equipment Index is representative of a specific company's turret lathe. In fact, the Machinery and Equipment Wholesale Price Index is made up of samples of production of many different kinds of machines and equipment produced by different contractors located all over the country. Third, it is assumed that the

past will forecast the future and that a line drawn through data points will predict future inflation. This might be wrong as few analysts can forecast an economic turning point.

Nevertheless, the index number approach to price analysis gives the analyst another tool for comparison. It can be used to check prices predicted by other methods of analysis such as parametric or detailed analysis approaches. The index number approach can also be used as a basis for price negotiation when the buyer is lacking substantive price data.

Price Escalation Clauses

There is a need for some Government contracts to contain a price readjustment arrangement providing for significant unanticipated fluctuations in the economy. This need is most apparent in those contracts that call for performance a long time in the future (more than two years), although sometimes the need exists for shorter term adjustment. Contracts that fall in the longer range category are typically large systems production contracts or multiyear production contracts.

The possibility of unanticipated fluctuation in the economy is one of the elements of cost risk in any contract. As the period of performance becomes further removed from the time the contract is written, the risk becomes greater.

Contractors normally include some contingency dollars in a cost proposal to compensate for this risk of cost overrun. As the risk becomes greater with longer periods of contractual coverage, the price of the contingency becomes unacceptably high from the Government's point of view. This risk can be shifted in part or in total to the Government through the use of a price adjustment clause.

One can identify two general approaches to constructing price adjustment clauses for economic fluctuations in large dollar, extended production efforts. One is to construct a clause to compensate for any and all changes in the economy. The other is to construct a clause to compensate only for abnormal fluctuations in the economy. Both approaches use some index number series as a basis for making a price redetermination at the conclusion of the effort.

The "any and all" fluctuations approach is simpler and easier to understand. If the index number forecast for some specified future period of performance is higher or lower than actual, then the contract costs originally predicted using the forecast index number would be adjusted to reflect actual index numbers extant at the time of performance. For a specific element of cost, the "any and all" fluctuation clause might include a repricing formula as follows:

$$\text{Price Adjustment} = \frac{\text{Actual Index} - \text{Forecast Index}}{\text{Forecast Index}} \times \text{Target Cost}$$

The probability of correctly predicting the level of the economy and its associated index number is low, thus making the need for some repricing highly probable. If the index numbers chosen accurately relate a particular product to the economy, this approach eliminates all of the contractor's risk associated with fluctuations in the economy.

The "abnormal" fluctuations approach assumes that a normal range of economic change can be defined and that prices will be adjusted only if the economic indicators fall outside of that normal range. Figure 2 portrays the concept.

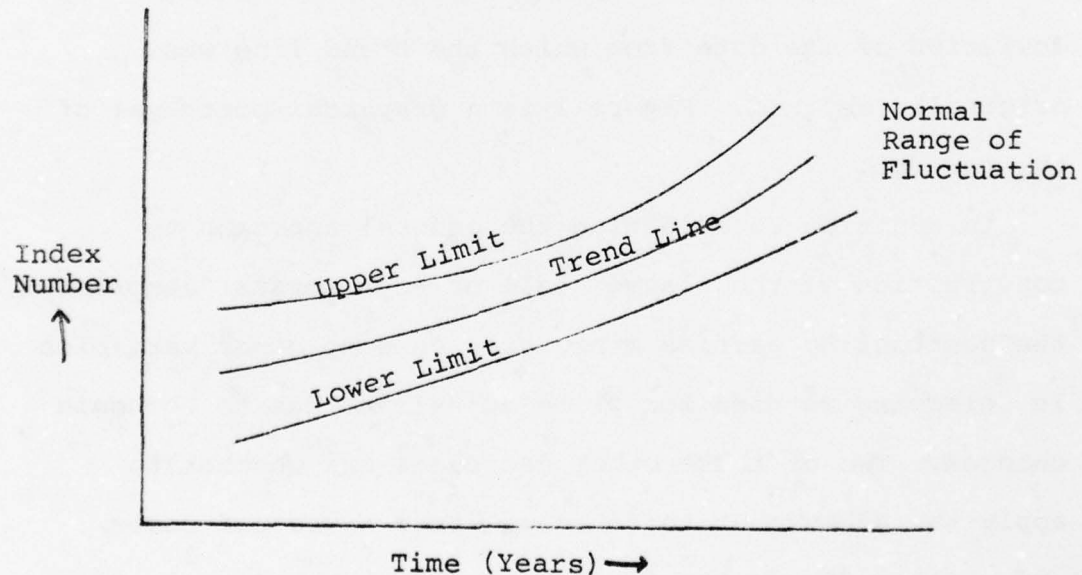


FIGURE 2
FLUCTUATION AROUND AN INDEX NUMBER TREND

This approach requires two formulations of the adjustment equation for each element of cost to be repriced. One formulation adjusts the costs upward if the actual index exceeds the high side of the range and the other formulation adjusts the costs downward if actual index falls below the low side of the range.

For example:

$$\text{Adjustment} = \frac{\text{Actual Index} - \text{High Forecast Index}}{\text{High Forecast Index}} \times \text{Target Cost}$$

$$\text{Adjustment} = \frac{\text{Actual Index} - \text{Low Forecast Index}}{\text{Low Forecast Index}} \times \text{Target Cost}$$

Selection of the range itself is a rather arbitrary process, but it can be generalized that the wider the range, the greater the amount of risk shifted to the contractor. A reasonable range might be plus or minus one standard deviation of the data from which the trend line was originally defined. Figure 2 is a graphical portrayal of the concept.

In addition to selecting the general approach to construction of the clause, "all or any" versus "abnormal," the contracting parties must agree on some other variables in selecting methods for price adjustment due to economic changes. Two of these other decisions are whether to apply the adjustment to forecast costs or actual costs and whether to use the forecast index or the actual index

as the denominator in the adjusting fraction.

The adjustment might be a function of either target costs or actual costs, e.g.:

$$\text{Adjustment} = \frac{\text{Actual Index}-\text{Forecast Index}}{\text{Forecast Index}} \times \text{Forecast Costs}$$

$$\text{Adjustment} = \frac{\text{Actual Index}-\text{Forecast Index}}{\text{Forecast Index}} \times \text{Actual Cost}$$

Opponents of actual costs as a basis for adjustment advance the thought that if overruns or underruns occur, the amounts of the overruns or underruns would unfairly influence the adjustment. Another argument against the use of actual costs is the difficulty in defining them since allowability of costs is often subject to negotiation. A third argument against the use of actual costs as the basis for adjustment is time delay. Often actual costs aren't audited for years after contract completion.

Advocates of actual costs as a basis for adjustment believe the purpose of the adjustment clause is to adjust the price for causes beyond the contractors control. Therefore, the adjustment should be made on the basis of actual costs whatever they might be.

Another decision facing the constructor of escalation adjustment clauses is the need to decide on which factor to use in the denominator of the adjustment fraction. Precedent has established that the denominator be the

actual index when actual costs are adjusted and that the forecast index be the denominator when forecast costs are to be modified, e.g.:

$$\text{Adjustment} = \frac{\text{Actual Index} - \text{Forecast Index}}{\text{Forecast Index}} \times \text{Forecast Cost}$$

$$\text{Adjustment} = \frac{\text{Actual Index} - \text{Forecast Index}}{\text{Actual Index}} \times \text{Actual Cost}$$

It is apparent that in a period of rising economic indicators, that the cost adjustment fraction (and the resulting adjustment) would be smaller if the actual index were used as the denominator. It is intuitively better (at least to this writer), to use such a smaller adjustment fraction with actual costs that already include the effects of inflation. On the other hand, for those adjustment equations based on forecast costs, it appears more fair to use the forecast index as the denominator of the adjustment fraction.

A third decision facing the constructor of escalation clauses is the choice of index series and the weights to apply to each series used. For example, one Air Force systems acquisition contract for aircraft uses two economic indicator series to adjust the price for inflation (6:43). The two series are the BLS, Wholesale Price, Industrial Commodities Index and a wage rate series from the BLS yearly average wage rates for the Durable Goods

category of Production Workers in Manufacturing by Major Manufacturing Groups. The Industrials Commodities Index is chosen to represent the materials portion of the aircraft price and is weighted 25% of the total price. The wage rate series is chosen to represent the labor portion of the price and is weighted 75% of the total price. The redetermination clause is of the form:

$$\text{Adjustment} = \frac{\text{Actual Index} - \text{Forecast Index}}{\text{Forecast Index}} \times \frac{\text{Forecast Cost}}{\text{Cost}}$$

The clause constructor needs to trade off clause complexity and the subsequent difficulty of constructing and administering the clause against level of accuracy desired. The above mentioned aircraft procurement escalation clause is simple and easy to construct and administer. The contracting parties take the risk, however, that the economic indicator series are not closely related to the airframe manufacturing industry. There is little consideration of indirect cost factors which often change at a different rate than direct cost factors. Campbell discusses the detrimental effects of ignoring indirect cost indexes in his "Aerospace Price Indexes" (3:13).

The method chosen to forecast the index trend is a fourth major consideration in clause construction. A

straight line regression analysis built on price index numbers of the 1960's will seriously underestimate 1970 prices indexes. It is a good idea to plot the data, discern a trend and best fit a trend model through statistical analysis for projection purposes. A straight line has not been a good tool for such projection in recent years.

The ideal contract clause for adjustment of price due to inflation does not seem to exist. If the clause closely approximates the economic changes of a specific product, it is complicated to construct and administer. If the clause is simple to construct and administer, it does not relate well to the product for which the economic adjustment is sought. Recognizing that all solutions are compromise solutions, the following ideas are suggested as a starting place from which to construct an adjustment clause.

First, select the normalcy band adjustment clause form. For example:

High Side Adjustment =

$$\frac{\text{Actual Index} - \text{High Side Forecast Index}}{\text{High Side Forecast Index}} \times \text{Forecast Cost}$$

This adjustment form uses a forecast index and a forecast cost (target cost). By using a forecast cost as a basis

for adjustment, the administrative problems associated with determining allowability of actual costs are avoided.

Second, select at least three index series to represent the price of the product. One series should be related to the materials used in or purchased for the product being priced. The second series should relate to direct labor of the type used to produce the product. The third series should relate to the indirect costs on the product being priced. Weights totaling 100% need to be assigned to each category of costs. After selecting the index series, each needs to be forecast for the period of performance. For short range forecasts (less than 2 years) an exponential smoothing model best fitting each set of data should be used. For long range forecasts (2 - 10 years) a trend model best fitting each set of data should be used. Generally speaking, one should use more than 10 years of data to discern this trend.

Third, the forecasted index numbers should be used to inflate the out-year price estimate from current dollars to future dollars for target pricing purposes. This task is necessary whether or not an economic adjustment clause is included in the contract.

Fourth, a width of the normalcy band for each series of data must be defined. A zero width band means that the Government assumes all the risk of inflation. Rather

arbitrarily, a normalcy band of \pm one standard error of the mean is suggested as a negotiation starting point for a normalcy band. This affords the contractor protection against "abnormal" inflation and the Government still does not assume all the risk. Each economic series would have a normalcy band. If actual index numbers move outside the normalcy band for the period being priced, the contract should provide that the price of the affected element (materials, labor or indirect) would be adjusted in accordance with the formulation. Such a clause should contain as a minimum; (1) the formulation of the repricing arrangement, (2) the index series sources to be used to determine the actual indexes when repricing, (3) an example of how the two parties expect the repricing formula to work if it is exercised.

Price Deflators to Facilitate Regression Analysis

Price deflators can be used to deflate prices to a constant dollar basis to facilitate regression analysis. Many times cost data are aggregated by function or category of incurrence for accounting purposes. These data are also related to the flow of time because of the practice of keeping accounts by accounting period. An example of such an account would be a general and administrative (G&A) account, one of the contractors indirect cost pools. G&A pool data are usually available

on a yearly basis as far back as the contractor keeps records. When the analyst needs to predict costs such as G&A costs for future years of operation, he needs to find some level of activity indicator that causes G&A costs to vary. An example of such an indicator might be the number of direct employees, number of total employees, cost of sales or other similar independent variables.

Before one begins the regression analysis of the dependent variable (pool dollars) on the independent variable(s) (level of activity indicator), the dollars need to be deflated to a constant dollar basis. This is because the dollars were actual dollars expended in different periods of time. These dollars include the effects of inflation and they have different values.

By selecting a price index number series that represents the kinds of costs that are in the aggregation, and deflating each dollar grouping by its corresponding index number, the effects of inflation can be removed. The dollars are converted to a constant (base year) basis suitable for regression analysis, forecasting and subsequent reinflation for pricing purposes. The following example is intended to illustrate the use of index numbers when forecasting manufacturing overhead costs for a future year of contractor operations. Table 7 is a summary of cost data keyed to the explanatory notes that follow.

TABLE 7
COST DATA SUMMARY

Year Number	1	2	3	4	5	6
Year	1967	1968	1969	1970	1971	1972
Actual Cost ^a	\$32,670	\$41,111	\$43,879	\$51,276	\$59,432	
Activity Level Direct Labor ^b Hours (DLH)	17,800	21,000	22,800	27,100	35,900	
Index Numbers ^c	100.0	104.8	108.9	112.4	114.8	
Deflated Costs ^d	\$32,670	\$39,228	\$40,293	\$45,619	\$51,170	
Activity Level Forecast (DLH) ^e						35,000
Deflated Over- head Cost Model & Deflated ^f Forecast				Deflated OH \$ Cost = A + B (DLH) = 17,688 + 0.96734 (DLH)		51,544
Index Nr. Cost Model and Forecast ^g				Index No. = A + B (year number) = 97 + 3.72 (year number)		119.3
Actual Cost Forecast ^h						61,492

TABLE 7 - Continued

Notes:

- ^aActual costs for past years of operation are collected from the contractor's accounting records. These costs may need to be adjusted to compensate for changes in the accounting system from year to year.
- ^bThe activity level selected to explain the variation in overhead costs from year to year is direct labor hours (DLH). Historical DLH's are collected for years corresponding to the overhead cost data.
- ^cThe index numbers listed here were constructed from contractor's indirect cost data for prior years using the weighted average of Price Relatives (current year weights) approach. The analyst might also have selected a previously constructed index series that was representative of the contractor's overhead cost pool make-up.
- ^dThe actual costs are deflated to constant 1967 dollars by dividing each year's overhead costs by the corresponding index number.
- ^eThe forecast of direct labor hours for the future year(s) is a function of the contractor's sales projection. Necessarily then, the contractor must assist the analyst with the forecast.
- ^fThe deflated overhead cost model is a simple straight line derived by regressing deflated costs on the corresponding activity level (DLH). The deflated overhead cost forecast is calculated from the cost model by inputting the forecast direct labor hours, 35,000.
- ^gThe index number cost model is a straight line derived by regressing the index number on the corresponding year number (1,2,3,4 and 5). The index number forecast was calculated from the cost model by inputting year 6.
- ^hThe actual cost forecast is calculated by multiplying (inflating) the forecast deflated overhead costs 51,544, by the forecast index number, 119.3.

PART VII

SUMMARY

This paper discusses the use of index numbers in Defense Contract Pricing. The early part of the paper surveys some different types of price index numbers, illustrates their construction and discusses some attributes and deficiencies of each. A weighted average of relatives is suggested as an instrument to combine previously constructed price index numbers and specially constructed price index numbers.

A later section discusses some of the many sources of previously constructed index number series. These are developed and maintained by agencies external to the pricing office. The externally constructed index numbers may sometimes be substituted for index numbers tailored to a specific procurement. Such a substitution may save the analyst time in exchange for loss of accuracy.

The task of forecasting index numbers is a time series analysis problem. Some statistical techniques such as regression analysis and exponential smoothing may be appropriate for this task. For short range forecasts, one may use graphical techniques with reasonable confidence.

It is observed that in recent years index number series no longer follow a linear pattern with respect to time.

Price index numbers may be used to analyze prices, adjust final prices paid to compensate for escalation of costs and deflate data to facilitate cost analysis. Examples of these uses are included in a final section of this paper. Also included is a discussion of variables to include in contract escalation clauses.

The use of index numbers in contracting pricing is just one of a series of tools that the complete price or cost analyst should master. This discussion should start the analyst along the path to such a mastery.

PART VIII
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